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Amplifiers

PART 2

By the Engineering Department, Aerovox Corporation

(Continued from the June 1937 issue)

5. AUDIO AMPLIFIERS: Audio-frequency amplifiers may be divided according to their type of coupling into resistance-coupled amplifiers, impedance-coupled amplifiers, transformer-coupled amplifiers and direct-coupled amplifiers.

The charts of Figures 4, 5, and 6 show the fundamental circuits, their equivalents and the gain obtainable at low, high and intermediate audio frequencies. Complete information of the constants for Resistance coupled amplifiers and their performance will be found in the R. C. A. application Note 67, Jan. 20, 1937.

Resistance coupled amplifiers have the advantage of economy while the frequency response can be made nearly flat. The phase distortion is less than that of other types of coupling except direct coupling. Disadvantages are: lower gain than impedance or transformer coupling with the same tubes and power supply and the tendency to "motorboating".

Impedance coupled amplifiers have the advantage that a lower voltage drop occurs across the load, making the plate voltage higher. The frequency response falls off at the low end as well as at very high frequencies, above the point where parallel resonance occurs. The drop at the low end can be minimized by placing a resistor across the plate choke. If the value of the resistance is 1/3 of the choke reactance at the lowest frequency, or less, the impedance of the combination will not vary more than a few percent over the audio range.

At the present state of the art, transformer-coupled amplifiers can be designed to have a frequency characteristic as good as that of a resistance-coupled amplifier. The gain of

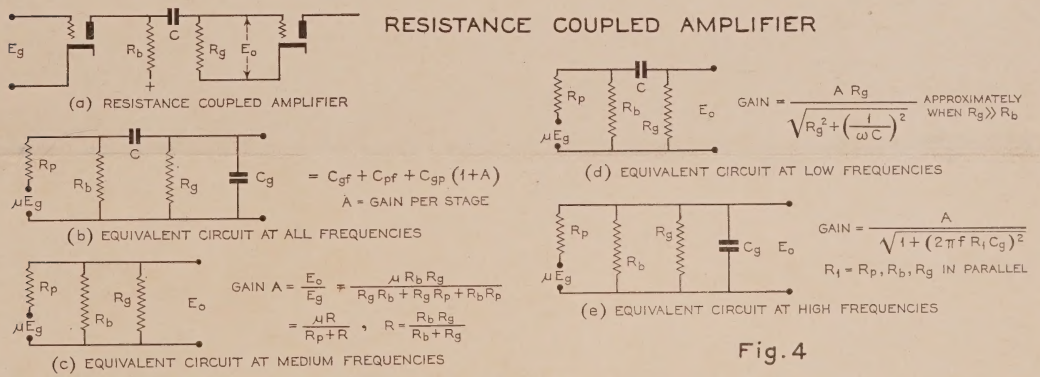
RESISTANCE COUPLED AMPLIFIER
(a) RESISTANCE COUPLED AMPLIFIER
(b) EQUIVALENT CIRCUIT AT ALL FREQUENCIES
$C_{gf} + C_{pf} + C_{gp}(1+A)$
A = GAIN PER STAGE
(c) EQUIVALENT CIRCUIT AT MEDIUM FREQUENCIES
GAIN $A = \frac{E_o}{E_g} = \frac{\mu R_b R_g}{R_g R_b + R_g R_p + R_b R_p} = \frac{\mu R}{R_p + R}$, $R = \frac{R_b R_g}{R_b + R_g}$
(d) EQUIVALENT CIRCUIT AT LOW FREQUENCIES
GAIN $= \frac{A R_g}{\sqrt{R_g^2 + \left(\frac{1}{\omega C}\right)^2}}$ APPROXIMATELY WHEN $R_g \gg R_b$
(e) EQUIVALENT CIRCUIT AT HIGH FREQUENCIES
GAIN $= \frac{A}{\sqrt{1 + (2\pi f R_t C_g)^2}}$
$R_t = R_p, R_b, R_g$ IN PARALLEL

Fig. 4

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IMPEDANCE COUPLED AMPLIFIER

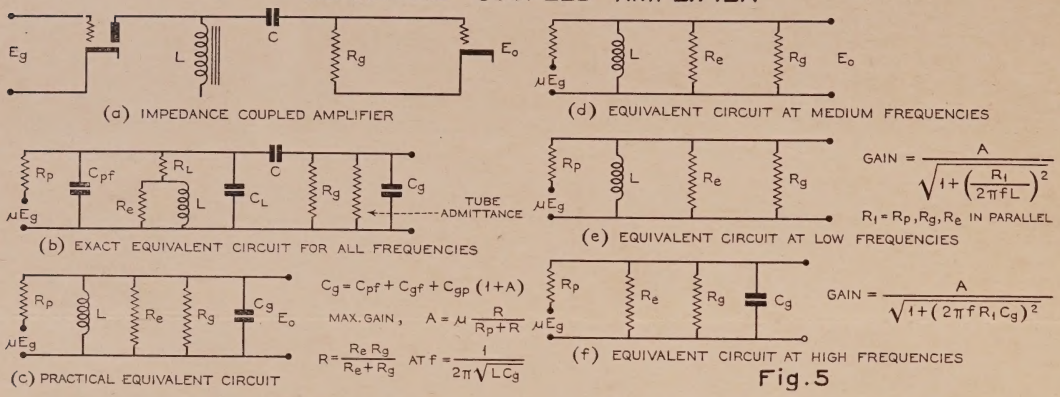


Fig. 5

the amplifiers is not as high as that of the resistance-coupled amplifiers using pentode tubes, and the cost of the transformers is very high. When sensitive amplifiers are used and a transformer is at the input, the hum problem is much greater than with r.c. amplifiers. Well shielded transformers are required and even then critical placing is necessary.

Transformer coupling is, however, the only way in amplifiers where the grid circuit takes power, as in class B and C ampliefirs.

Direct coupling is really a special case of resistance coupling. In such circuits the plate of the first stage is directly connected to the grid of the next, which requires some juggling with power supplies. Since the load between stages is a resistance and the coupling elements per stage are reduced, this type of amplifier can be made to have a better response than any other type. Response at low frequencies is better and delay distortion is less. The main difficulties are the tendency to drift due to temperature changes and the difficulty in designing amplifiers of many stages. It is, however, possible to make an amplifier employing a drift-corrector which makes the system practical for amplification of a.c. signals but not for d.c. Practical circuits of a single ended amplifier and a push-pull amplifier are shown in Figure 7.

TRANSFORMER COUPLED AMPLIFIER

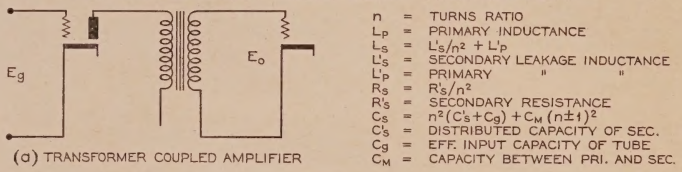
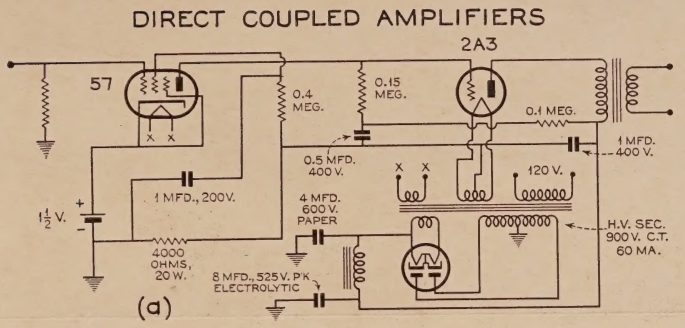

Eg
Eo
(a) TRANSFORMER COUPLED AMPLIFIER
n = TURNS RATIO
Lp = PRIMARY INDUCTANCE
Ls = L's/n² + L'p
L's = SECONDARY LEAKAGE INDUCTANCE
L'p = PRIMARY " "
Rs = R's/n²
R's = SECONDARY RESISTANCE
Cs = n²(C's+Cg) + CM (n±1)²
C's = DISTRIBUTED CAPACITY OF SEC.
Cg = EFF. INPUT CAPACITY OF TUBE
CM = CAPACITY BETWEEN PRI. AND SEC.
μEg
Rp
Re
Lp
Ls
Rs
Cg
(b) APPROXIMATE EQUIVALENT CIRCUIT
Eo/n
GAIN = 2πf Lp μn / √((2πf Lp)² + Rp²)
(c) EQUIVALENT CIRCUIT AT LOW FREQUENCIES
Cs
GAIN, A = μn (Re/(Rp+Re)) (1/ωCs / (ω²Ls Cs − 1))
= μn (APPROXIMATELY)
(d) EQUIVALENT CIRCUIT AT MEDIUM FREQUENCIES WHEN Lp AND Cs ARE IN PARALLEL RESONANCE.
GAIN = (μn/ωCs) / √((Rp+Rs)² + (ωLs − 1/ωCs)²)
(e) EQUIVALENT CIRCUIT AT HIGH FREQUENCIES

Fig. 6



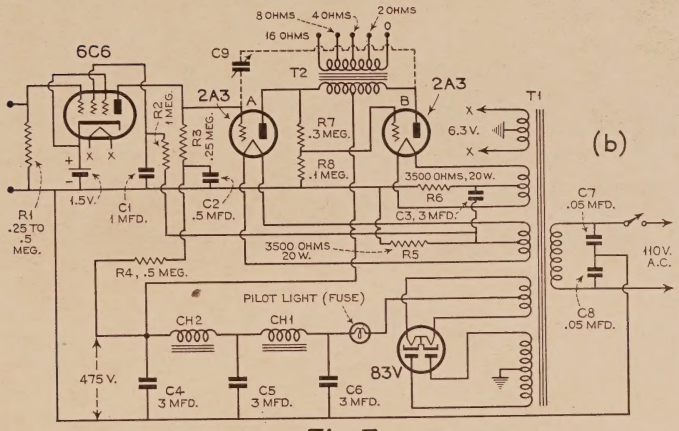


Fig. 7

6. FEEDBACK: When a portion, B, of the output of an amplifier having a voltage amplification A, is fed back to the input, the gain becomes:

$$\frac{A}{1 - AB}$$

in this case B is positive for regeneration and negative for degeneration. Non-linear distortion, noise and hum will be multiplied by the factor—

$$\frac{1}{1 - AB}$$

These equations hold when the feedback voltage is in series with the input signal and there are no additional phase shifts due to reactances.

Figure 8 shows several ways of arranging the feedback circuit in transformer-coupled and resistance-coupled circuits. There is a phase shift of 180 degrees in each stage which should be taken into consideration; in addition, there is a phase shift in each stage which varies with frequency but is never more than 90 degrees. This fact limits the number of stages to be bridged by the feedback circuit. When the sum of the shifts amounts to 180 degrees, oscillation starts unless the gain at that point is less than one. For this reason, degeneration is limited as a rule to three stages and to about 30 db.

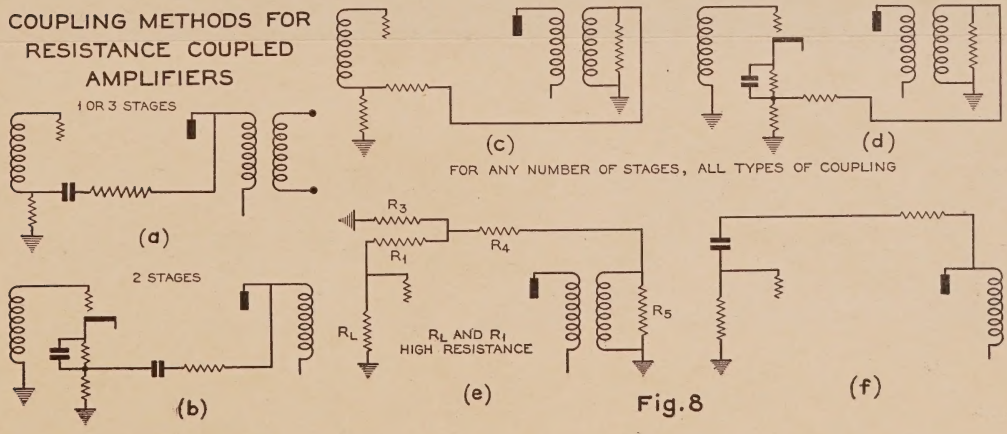
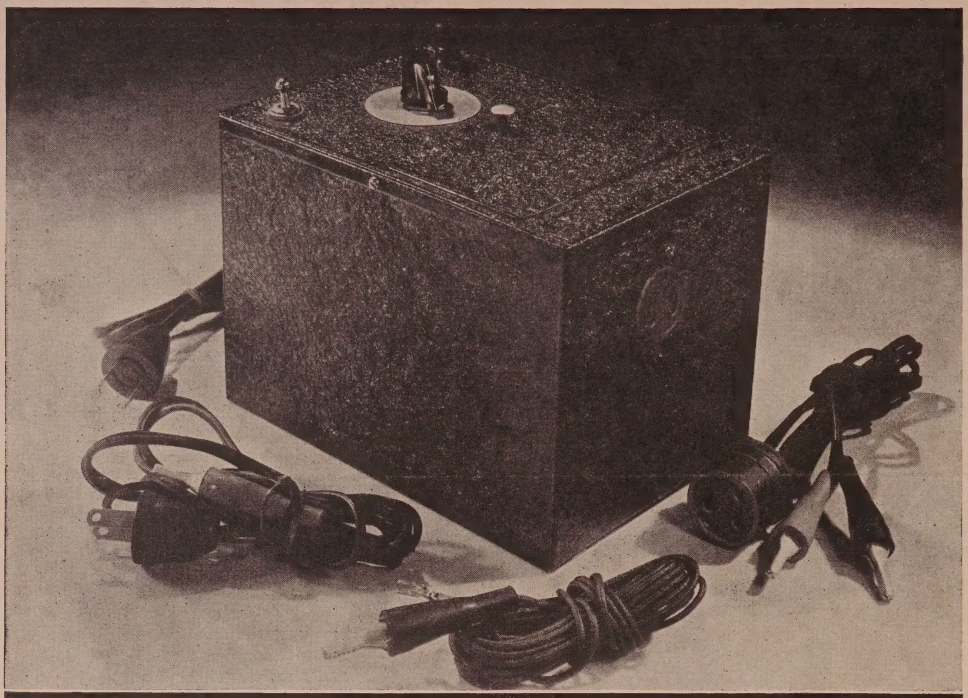


Fig. 8



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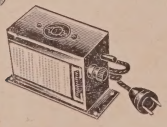

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